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UNDERCOOLING OF PEACH BUDS

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One method of determining hardiness of fruit buds is that of estimating the percentage of injury after the buds have been subjected to low temperatures under natural or artificial conditions. West and Edlefsen[1] give a table compiled from the results of other workers showing the danger points for various kinds of fruit at three different developmental stages. The danger point for peaches at the time the petals are closed, but are just showing color, varies from 20° to 29° F. Their own very extensive studies show that Elberta peach buds in full bloom are safe at 29° F. and above. They state that occasionally temperatures of 26°, 27°, and 28° F. do no damage, but that usually one of 28° F. kills from one fourth to one half the buds, and a temperature of 22° F. kills nine tenths, while one of 18° F. fails to kill all of them. The method of estimating the injury is not very satisfactory in cases where the *degree* of hardiness is to be determined. It is very desirable that some convenient physical measurement of hardiness of fruit buds be worked out in order to ascertain more definitely the relation between the resistance offered by such buds to low temperature and various environmental conditions such as moisture, temperature, fertilizers, etc. Johnston[2] suggested that the ratio of water content to dry weight of fruit buds might serve as a possible index, but sufficient work has not yet been done to warrant its general use. Experimental results of various investigators have not always been in agreement regarding the value of the freezing-point depression of expressed saps as an indication of hardiness. Furthermore, there are a number of important conditions necessarily neglected in measuring the undercooling of expressed saps. For example, it has been shown by Bigelow and Rykenboer[3]

> That decidedly greater supercooling can be produced in capillary tubes than in tubes of larger diameter.

[1] West, F. L., and Edlefsen, N. E. Freezing of peach buds. Jour. Agr. Res. **20**: 655–662. 1921.

[2] Johnston, E. S. An index of hardiness in peach buds. Amer. Jour. Bot. **6**: 373–379. 1919.

[3] Bigelow, S. L., and Rykenboer, E. A. Capillary phenomena and supercooling. Jour. Phys. Chem. **21**: 474–512. 1917.

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The size and shape of the capillary water films within the plant tissues undoubtedly have a marked influence on the amount of undercooling necessary to start crystallization. Also, the amount of water held by imbibition depends on the colloidal properties of the bud tissues. The degree of hardiness is so modified by these conditions that undercooling and freezing-point measurements of expressed saps do not in all probability indicate a true index of hardiness.

Numerous theories[4] have been advanced concerning the mechanical cause of injury due to low temperatures. Whether the harmful results come from failure of the protoplasm to regain water lost when ice crystals form or from precipitation of proteins or from other metabolic changes accompanying low temperatures, there is evidence that the injurious effects come at the time that ice crystals form or shortly thereafter. It must not be understood, however, that injury always results from water crystallization alone. Experiments were carried out during the early part of 1921 (January to March) with the idea of comparing the undercooling of sap within fruit buds of two peach varieties. The method used was somewhat similar to that described by Harvey.[5] A copper-constantan thermo-junction made of number 40 wires and encased in a small glass tube (0.4 mm. diam. by 3.0 mm. long) was cemented to the end of a piece of hard rubber tubing. When temperature measurements were made this junction was inserted into the upper end of a detached bud and lowered into a double-walled chamber surrounded by a freezing mixture of ice and salt. The bud was so suspended as to be free from contact with the walls of the cooling chamber. The cooling chamber was of such a size that it fitted very conveniently through the cork stopper of a pint thermos bottle containing the freezing mixture. The constant-temperature junction was placed in a similar thermos bottle filled with melting ice. This constant-temperature junction could very easily be kept at 0° C. for two days. A galvanometer similar to that described by Shreve[6] was calibrated and used to measure the temperature differences of the junctions. The copper leads were connected directly to the binding posts of the galvanometer so that a continuous reading could be made. Between each two successive readings the zero point on the galvanometer scale was obtained by a key connected directly with the binding posts. A temperature difference of 0.1° C. could very easily be detected.

In the experiments here reported fruit buds from two trees (Elberta and Greensboro) were studied. These trees, located near each other in a nine-acre peach orchard, were growing under very similar conditions.

[4] A brief review of a number of these theories and a bibliography of 50 titles dealing with the hardening process in plants is given by Dr. R. B. Harvey in "Hardening process in plants and developments from frost injury." Jour. Agr. Res. **15**: 83–111. 1918.

[5] Harvey, R. B. Importance of epidermal coverings. Bot. Gaz. **67**: 441–444. 1919.

[6] Shreve, Edith B. A thermo-electrical method for the determination of leaf temperature. Plant World **22**: 100–104. 1919.

Data showing the average temperature at which crystallization began and the average temperature immediately after crystal formation are designated in table 1 as "Undercooling" and "Freezing point" respectively. The

TABLE 1. *Data Showing the Temperature of the Freezing Mixture, the Average Temperature at which Crystallization began (Undercooling), and the Average Temperature Immediately after Crystal Formation (Freezing Point), together with the Ratio of Water Content to Dry Weight of Fruit Buds of the Elberta and Greensboro Peach.*

Date	Temperature of Freezing Mixture	Undercooling		Freezing Point		Ratio of Water Content to Dry Weight	
		Elberta	Gr'boro	Elberta	Gr'boro	Elberta	Gr'boro
1921	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*		
Jan. 21	14.0	17.8	18.5	21.0	20.5	....	....
Jan. 26	15.8	19.2	19.6	22.1	21.6	0.89	0.82
Feb. 12	4.3	17.8	17.6	20.3	19.6	1.03	0.94
Feb. 18	7.5	18.1	18.7	21.6	21.0	1.20	1.05
Feb. 25	8.6	18.5	18.9	21.6	21.7	1.21	1.10
Mar. 5	6.4	19.0	19.2	22.8	22.3	1.61	1.31
Mar. 11	3.2	19.4	20.1	24.4	24.8	2.53	2.01
Mar. 14	2.8	22.3	20.5	24.6	24.4	2.87	2.57

temperature of the cooling mixture was not exactly the same on any two days, thus making some measurements taken on different days not strictly comparable, but the data of the two varieties on any one day are comparable. All the measurements were made in the laboratory shortly after the twigs had been cut from the trees. Twigs of similar size and similarly located on the trees were selected. The lower ends of these twigs when brought to the laboratory were cut off under water and placed in bottles of water in order to minimize the danger of drying out. Buds from the two varieties were alternately measured in pairs as a further precaution for securing comparable data between varieties. The time usually required for a bud to undercool was about two minutes, although this varied somewhat with the temperature of the freezing mixture. These same data are represented graphically in figure 1.

In figure 1 the lower pair of graphs represents the undercooling and the upper pair the freezing point. From February 12 to March 14 each set of graphs shows a decided rise. This indicates that the sap in these buds as they continue to develop has a higher freezing point and that it can be undercooled to a less extent. The data of the first two observations are scarcely comparable with those of later dates because of the great difference in temperature of the freezing mixtures, the rate of cooling being slower in the former cases than in the latter. There is very little difference between the freezing points of buds of these two varieties. Likewise there is but little difference in their undercoolings. Elberta, which is considered the less hardy variety, has in most cases a slightly lower undercooling point, which is just the opposite of what might be expected. On March 14, however, shortly before the petals opened, the extent of undercooling is 22.3° F.

as compared with 19.4° F. three days previous. The undercooling value of the Greensboro buds rises but 0.5° F. during the same period. On March 14 the Elberta buds were about a day further developed than the Greensboro, as indicated by the difference in time required for their petals to open when

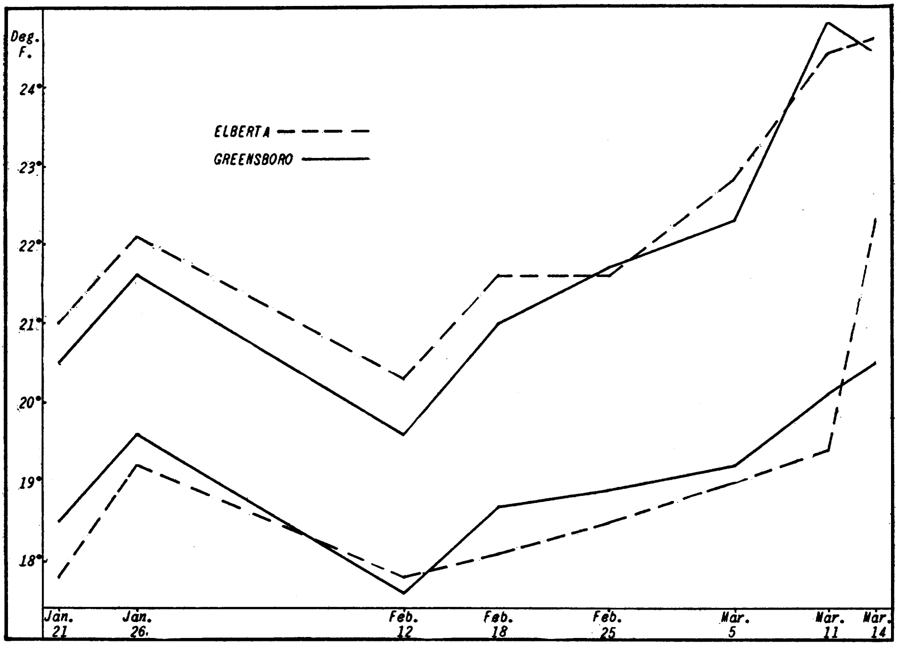

FIG. 1. Graphs showing variation in the freezing point (upper pair) and undercooling (lower pair) of fruit buds in the Elberta (broken lines) and the Greensboro (continuous lines) peach.

placed in the greenhouse. Whether or not these undercooling measurements mean that Elberta and Greensboro fruit buds are of practically the same degree of hardiness from January 21 to within a few days of the time the petals open can not be determined from the scant data of this one year.

The extent of undercooling is probably a more important index than the actual freezing point. The freezing point in all probability is a more constant value depending largely on the concentration of the cell sap, while the extent of the undercooling is further conditioned by agitation of plant tissues due to wind movement, size of capillary films, rapidity of cooling, etc. The undercooling here obtained in the laboratory is not necessarily the undercooling that would occur outside under natural conditions. In the former case the cooling was very rapid as compared with similar changes under the usual natural conditions. Neither must these undercooling temperatures be confused with the actual killing temperatures. As a matter of fact, the actual minimum temperature[7] between February 18 and

[7] These temperatures were recorded by Mr. Thomas H. White, who has charge of the local U. S. Weather Bureau Station.

25 was 13° F., while the undercooling in the laboratory on February 18 was 18.1° F. for the Elberta buds. This temperature of 13° F. apparently did not injure the buds in the orchard at that stage of their development. The peach blossoms on the trees in this same orchard were, however, practically all killed on March 29 and 30 by temperatures of 25° and 20° F. respectively. These higher temperatures came at a time when the buds were in a more tender condition. If the experiment here reported could have been continued, it would undoubtedly have shown a further rise in the undercooling graphs.

Some of the buds from twigs cut on March 14 were dipped into water and then frozen while a thin film of water adhered to the bud-scales. These data and those of Greensboro buds sprayed and unsprayed are shown in table 2. Practically no difference is seen in either the undercooling or the

TABLE 2. *Data Showing the Undercooling and Freezing Point of Dry and Wet Buds, and of Sprayed and Unsprayed Buds*

Condition of Buds	Undercooling		Freezing Point	
	Elberta	Greensboro	Elberta	Greensboro
	Deg. F.	*Deg. F.*	*Deg. F.*	*Deg. F.*
Dry	22.5	19.9	25.0	25.2
Wet	23.4	22.3	29.5	29.3
Sprayed	....	20.1	....	24.8
Not sprayed	....	20.3	....	25.0

freezing points of the sprayed and unsprayed Greensboro buds. The Greensboro tree used throughout this series of experiments had been sprayed with lime-sulphur solution on the day previous to this particular experiment. The unsprayed Greensboro was growing near by. Buds of both varieties show a greater undercooling when in the dry condition than when wet. Crystallization seemed to be more rapid and complete in the case of wet buds, as is indicated by the higher temperatures obtained in the freezing-point columns. These data obtained from dry and wet buds, although meager, indicate that wet buds freeze at a higher temperature than dry buds. This is in agreement with the results obtained by Harvey,[8] and by Chandler[9] who states that

> Tissue with a wet surface killed worse at a given temperature than did tissue with no moisture on the surface.

West and Edlefsen[10] in their orchard experiments of 1912 likewise found that wet buds and blossoms were killed at low temperatures which did no injury to similar buds and blossoms in a dry condition.

[8] Harvey, R. B. *Op. cit.*

[9] Chandler, W. H. The killing of plant tissue by low temperature. Univ. Mo. Agr. Exp. Sta. Res. Bull. 8. 1913.

[10] West, F. L., and Edlefsen, N. E. Orchard heating. Utah Agr. Coll. Exp. Sta. Bull. 161. 1917.

Summary

By means of a thermo-electrical method the extent of undercooling of Elberta and Greensboro fruit buds exposed to the low temperatures of freezing mixtures was determined.

The data obtained indicate an increase in the tenderness of these buds with the approach of spring, and that just before the petals opened the buds of the Greensboro variety withstood a greater undercooling than those of the Elberta.

Other data obtained indicate that wet buds freeze at a higher temperature than dry buds. A period of cold weather immediately following a rain is thus apparently more dangerous to fruit buds of the peach than cold weather alone.

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